







## Article

# Nuclear Energy Development in Bangladesh: A Study of Opportunities and Challenges

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**Abstract:** It is a challenging task for Bangladesh to meet its increasing demand of energy while its economy is rapidly growing. Though prices of oil, coal, and fossil fuels around the world have been volatile, the price trend in Bangladesh demonstrates a persistent rise in the immediate past. This is further exacerbated by depleting reserves of natural gas. Cumulatively, these two effects heighten Bangladesh's energy needs. Bangladesh presently mitigates her energy requirements predominantly through natural gas, supplemented by a handful of coal and furnace oil plants. Consequently, due to scarcity of natural gas, oil and coal resources, nuclear power surfaces as a palatable strategic option for Bangladesh's future development agenda. However, a successful nuclear power program entails an extensive infrastructure. Just like the other nuclear energy-producing countries, Bangladesh also face challenges to safeguard the health and security of nuclear reactors, the proper management for nuclear waste treatment and the security concerns over the safe usage of nuclear materials. Additionally, the development of nuclear energy is also bewildered because of the complex nature of fission technology, lack of efficient human resources, and non-existence of proper legal instruments to guide safe nuclear power production. Moreover, the further challenges include the questions, for example: whether the nuclear power plant project is supported by the mass people or not? What are the strategies for nuclear waste disposal? Whether the recent initiatives for nuclear energy production is necessary or the country should more concern with renewable sources? This paper evaluates the nuclear energy development in Bangladesh. It operates under qualitative methodological framework and utilises secondary sources for analysis. We advance several recommendations in this paper to remedy the highlighted issues: (1) creating a comprehensive legal and regulatory system; (2) fortifying home-based technology of nuclear development and simultaneously localising of foreign-based technology; (3) reducing the cost of nuclear energy production; (4) fast-tracking the procedure of efficient development of nuclear technology; (5) accelerating the procedure of switching to more

efficient reactor and nuclear fuel cycle, and (6) conducting effective profile-raising activities to generate greater awareness and spur common acceptance.

**Keywords:** nuclear energy regulations; public acceptance; nuclear energy safety and security

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## 1. Introduction

Bangladesh is in the stage to become the 33rd nuclear power-producing nation after the successful construction work at Rooppur, Pabna [1]. The Rooppur Nuclear Power Plant (RNPP) is expected to generate additional 2400 MW of power to the national grid by the year 2024 [2], helping the nation to address the expanding demand for electricity. The venture is being executed by the state-run Bangladesh Atomic Energy Commission (BAEC) under the help of the Ministry of Science and Technology. In addition, Russian State Energy Commission (ROSATOM) is providing the financial, technological and technical support to the power plant.

The consistent rise in the prices of oil, coal, fossil fuels as well as the lack of natural gas reserves indicate the struggle of Bangladesh for energy demand [3]. Currently, the large portion of the country's energy is supplied through natural gas, while it has also a few coal- and oil-based power plants. The environmental impact of the uses of fossil fuels should not be discounted either [3]. The impact of fossil fuels on the environment is widely documented [4]; moreover, carbon dioxide emissions accelerate global warming and man-made climate change dynamics. In addition to carbon dioxide, other deleterious gases such as carbon monoxide, nitrogen oxide, and sulfur dioxide are released into the atmosphere as a result of combustion emanating from non-renewable fossil sources like oil, coal, and natural gas. Besides, lead and particular matters cause serious damages to the surrounding environment [5]. In such case, nuclear power plants can reduce fossil fuel consumption and keep the environment clean from the greenhouse gas emissions. There is also a public perception that nuclear fuel costs greenhouse gas emissions, however, the recent technological development relating to fission technology has developed significantly which made the nuclear power generation more environment friendly rather than generating electricity from fossil fuels [6]. As per research findings of the World Nuclear Association (WNA), emissions discharged throughout the life-span of all the prominent renewable sources of energy (e.g., solar energy, wind power, hydro-electric, biomass, etc.), along with nuclear sources, were comparable and substantially below than the ones from the fossil fuels [7].

Though there remains negative perception towards nuclear energy in the United States (US) and Europe, however, fast growing economy countries such as Bangladesh need such energy source in order to ensure the continuous supply of electricity to the country. It is widely recognised that there remains a strong relation between the energy supply and economic development [8]. In addition, the negative perception towards nuclear energy might deflate because of the increasing prices of the electricity as the prices of natural gas and oil increased rapidly. In Bangladesh, the present government promised to ensure the continuous supply of electricity to all citizens by the year 2021 [9]. The promise also includes to supply the energy with cheapest and reliable way. Consequently, in case of Bangladesh, nuclear power energy source seems to be one of the best alternative sources that could be utilised in order to achieve the nation's social and economic priorities.

## 2. Current Status of Nuclear Energy Development in Bangladesh

The RNPP program is a very important project for the people of Bangladesh. The idea of building a nuclear power plant was developed in the year 1961 [10]. From that time the chosen primary site for the power plant was the area of Pabna, Rooppur. After several delays for so many years, the Pakistan government shifted the nuclear power plant project to Karachi. After the independence, the government of Bangladesh again took over the project and decided to set up a nuclear power plant

that has a capacity of 200 MW at Rooppur. A French company named as M/S Sofratome conducted the feasibility test for this project [10]. However, the project never saw the light of the day and it was delayed until 2009. In 2009, the government of Bangladesh took up the power plant project very seriously and contacted Russia about the power plant project since Russia is experienced in nuclear energy production.

The Rooppur (alternative spelling: Ruppur) site is situated in the divisional district of Pabna, which is nearly 100 miles north-west of capital Dhaka. This site was chosen in 1963, and subsequently the land was procured [11]. Bangladesh government at the time officially endorsed the project for a series of plant proposals after national independence in 1971. The first post-independence proposal in 1980 entailed installation of a 125 MWe nuclear power plant, this however did not materialise [11]. Meanwhile, as demand and grid capacity increased, the reality of a bigger plant began to make more economical and practical sense. As such, the government proclaimed its intention to establish this plant in Rooppur again in 1999. Two years later, Bangladesh government enacted a national Nuclear Power Action Plan. Four years after that, it signed a cooperation pact with China. By 2007, the country's Atomic Energy Commission (BAEC) drafted a proposal for two separate 500 MWe reactors in the same location to be developed by 2015. The projected cost at the time was between USD 0.9 and USD 1.2 billion for the first unit (600 MWe). The higher capacity 2nd unit (1000 MWe) was anticipated to cost between USD 1.5 and USD 2.0 billion [12].

In the meantime, in April of 2008, upon queries from China, Bangladesh government restated its intent to partner with China in building the nuclear power plant in Rooppur. China too reiterated its offer of financing provisions. The International Atomic Energy Agency (IAEA) also approved a technical assistance project for the Rooppur Nuclear Power Plant with an estimated application around 2009–2011. Later, the plan was revised to enlarge the capacity of one plant to 1100 MWe [12]. Other than China, Russia and South Korea too had expressed interest in financing the project(s) as well as providing technical expertise to establish the power plants. In March of 2009, Russia formally tendered a bid to build the aforesaid plant in Rooppur.

On 13 May 2009 BAEC and ROSATOM signed a Memorandum of Understanding (MOU) on peaceful use of nuclear energy [13]. Initially Russia gave a proposal for a technologically advanced power plant which had not received international license. However, the proposal was rejected by the government of Bangladesh who eventually chose the commonly used VVER-1200 reactor technology [14].

At bilateral governmental levels, a mutual agreement was established between Russia and Bangladesh, which serves as a legal platform for cooperation in issues such as nuclear site selection, design, construction related issues, operating power plant, research on reactors, water desalination plants, and particle accelerators [10]. Among other aspects under the umbrella of this intergovernmental agreement include waste management related to supply of fuels. As per the agreement, Russia will be responsible for management of waste and subsequent decommissioning. On 2 November 2011, an inter-governmental agreement between Bangladesh and Russia was signed to carry on the RNPP project for the nuclear power plant construction [13]. In addition, ROSATOM entered into a treaty with BAEC in February of 2011 to build two 1000 MWe class reactors in Rooppur [10]. Rooppur's proximity to a high-voltage direct current link (HVDC) with India is worth mentioning. Moreover, the site straddles a planned route of 600 kV high-voltage direct current link spreading across the western portion of Bangladesh. This was followed by another bilateral treaty in November 2011 for a project expected to be established by the Atom Story Export (ASE) [10]. AEP's representatives in Moscow said in 2014 that the plant was scheduled to be of AES-2006 variety. The reactor model was supposed to be V-392M, and the reference plant is Novo Voronezh II. Power Machines were to be responsible for providing high speed turbine generators [10].

Later in the May of 2012, Bangladesh parliament saw introduction of a Nuclear Energy Bill, with the vision of commencing work in 2013 to set up a regulatory authority: Bangladesh Atomic Energy Regulatory Authority (BAERA) [10]. The proposal, as presented in the parliament, was that the project envisioned a 5000 MWe nuclear power generation capacity by the year 2030. Moreover,

a second plant was promised to be constructed in the southern vicinity of the first plant once it becomes operational [10]. The following Table 1 shows Government's Vision with nuclear power plants.

**Table 1.** Different sources of power and their heat value.

	Type	Capacity	Construction Starts	Commercial Operation
Rooppur 1	AES-2006/V-392M	1200 MW	August 2017	2023 or 2024
Rooppur 2	AES-2006/V392M	1200 MW	2018	2024 or 2025

The Minister of Science and Technology of Bangladesh has always confirmed that they are working closely with the International Atomic Energy Agency (IAEA) in order to ensure the safe nuclear energy production [15]. The government of Bangladesh is following the IAEA's 'Milestone' approach to build the national structure for the RNPP Project with reference to the 19 infrastructure issues which include the protection for the radiation, nuclear safety, legislative framework and planning for emergency condition etc., [15]. He also added that the ministry hosted several missions from the IAEA in order to facilitate the technological advancement of the power plant. The director general of IAEA also visited the RNPP site. The director general said he is convinced and narrated that the project will be a safe and successful one [15]. The IAEA director general also joined Abu Dhabi conference to present the RNPP project to the whole world.

The present condition of the project is very promising. The construction of the entire supporting infrastructure is finished in the first phase. The first concrete was poured on 30 November 2017 to the basement of RNPP in the Pabna district. The nuclear power plant (NPP) is expected to start commercial production of electricity in 2022.

### 3. Opportunities and Driving Factor's for Bangladesh's Nuclear Energy Development

Amidst the renewable sources of electrical power, nuclear energy turns out to be much of a lucrative pick within the wellspring of energy. And as we speak, this sheer power-source cater to 4.8% of this planet's call for energy and 9.7% of the Organization for Economic Co-operation and Development's (OECD; the OECD is a group of 34 major countries that does not include rapidly developing, high-energy consuming economies such as China and India.) energy requisite [16]. Be that as it may, the quest persists on how reliable the nuclear energy is in contrast with the alternative wellsprings of energy, for instance, hydroelectric and photovoltaics pertain to environmental and safety matters, economic viability, and keeping the future frame of mind.

Choosing and proper implementation of these energy technologies require consideration of various factors. For instance, location is one such vital factor. To exemplify, wind turbines demand powerful gust of wind and vast flat stretches of land, photovoltaics operate in optimum within territories drawing sunlight year-round, and hydroelectric power needs huge fast-streaming water-ways [17].

To avail the supply of conventional fossil fuel is a crucial factor as well since its transportation can be quite pricey. For example, France generates 80% of their total electricity by using nuclear power plants as the country has virtually has zero natural fossil fuels [18].

Nonetheless, the expenses of nuclear power are difficult to pin-point, which again relies on numerous factors. While putting coal, gas, and oil in comparison with nuclear energy, by and far, the latter turns out to be an expensive alternative [19]. The strength of nuclear energy is its colossal steadfastness of 'Price' since fuel represents only 31% of production costs [20]. Fuel costs soar up to 80 to 90% when electricity is generated by consuming coal or natural gas [20]. This makes fossil-fuel plants electricity production exceedingly sensitive due to price-fluctuations in coal and gas.

Nuclear energy's appeal sprawls in vast quantities, for example, its "cleanliness" (environment-friendly), enormous fuel energy density and inexpensive transportation. (1 g of uranium can produce approximately  $90,000\times$  more energy as 1 g of coal [21]) Moreover, the technology underpinning nuclear energy is highly-advanced than that of photovoltaics, for instance, the technology

which is still a work in progress since energy efficiencies have improved. Consequently, nuclear power plants rapidly prompted a huge energy supply since the 1970s.

However, evolution has backed off because of escalating expenses from financing challenges, increased safety regulations, and prices of competitive technology. According to the opinion of experts, the future growth of fission technology should be limited as they fear with the security and safety of such technology [22]. However, such technology, undoubtedly is very prospective for the countries tagged-developing (rapidly), such as India and China, where mounting expenses are not much of an issue. Therefore, nuclear energy is still a lucrative choice for the less-developed countries (LDC). Furthermore, it is undeniable that extant nuclear technologies applied in industries were products of countries advanced in technology and economic wealth. As such, corresponding governments continue to maintain a degree of investment on a yearly basis to develop safe and more secure nuclear power plants like small modular reactors [23]. If this technology evolves it has the potential to change the market. Additionally, government policies too are considered to have considerable ramifications on the energy market for nuclear and other renewables in these countries [24]. Thus, nuclear energy certainly promises a very bright future for both developing and developed countries [25].

There is an acute shortage of electrical power in the fast economy growing of Bangladesh. The Bangladeshi government has taken the initiative to construct and operate a nuclear power plant in Rooppur to address the shortage of electricity. The prospects of turning into a nuclear energy powered country are enormous.

At present, Bangladesh faces an enormous electricity shortage that has affected non-agricultural employment, the important textile industry and so on. There is an average of 3000 MW at peak demand where the actual shortage of demand is 2000 MW [26]. If Bangladesh goes forward with a nuclear power program, it is certain that manufacturers and investors within the country and around the globe will be setting up factories and facilities in Bangladesh. Because of the nuclear power plant, the county can become a large-scale manufacturer with its skilled manpower of a small and medium scale industries. Such industrial growth will also help to reach the government's goal to increase exports and GDP.

Since Bangladesh is situated on low and flat lands, the low water flows and air flows create low chances for hydropower or windmill generation other than in the hilly regions in the North and the Northeast. The only single hydropower power station is Kaptai, located across the river Karnafuly and has a capacity of only 230 MW, which is less than 5% of the nation's total power [27], so there is no other option rather than establishing nuclear power plant to meet the nation's electricity demand.

As nuclear technology in 21st century continues to advance whilst producing very little amounts of greenhouse gases, there remains no option for the government of Bangladesh other than to choose the promising nuclear energy for the country. Whether nuclear energy is a sustainable energy option or not, might be a debatable issue; however, keeping the current stage of environment in mind, nuclear energy definitely is an imperative option for Bangladesh to save its environment from the enormous carbon emissions of fossil fuels.

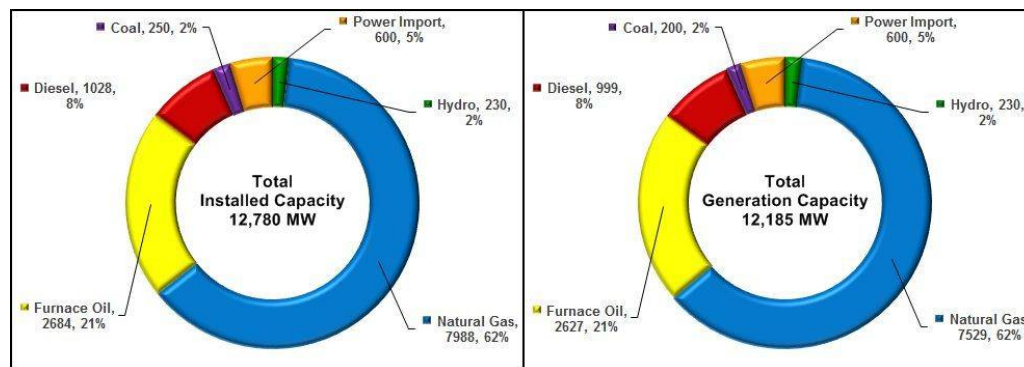
Bangladesh needs a stable and sustainable source of energy and the RNPP is a prospective solution to this. The following Table 2 exemplify the efficient energy production through nuclear means. The table presents a chart which shows that nuclear energy generates about 1000 times more energy than other energy sources. Table 2 also provides an overview which proves the affordability of nuclear energy.

**Table 2.** Different sources of power and their heat value [28].

Type of Fuel	Heat Value (MJ/kg)
Firewood	16
Brown Coal	9
Black Coal (low quality)	13–20
Black Coal	24–30
Natural Gas	39
Crude Oil	18,845–4638
Natural Uranium (in light water reactor)	500,000



Some of the challenges faced by the Bangladesh government in improving the power generation scenario include corruption at administration level, out-dated infrastructure, massive system losses, regular delays in the installation of new plants, inconsistent power supply, theft of electric lines, load-shedding, blackouts, and lack of financial resources to troubleshoot and maintain the existing power plants. As per statistics of August 2016, Bangladesh enjoyed a gross electricity generation capacity of 12,780 MW [29], as illustrated in Figure 1. Out of this, natural gas was the largest contributor at 62%, while furnace oil, diesel, cross-border imports from India, and hydro-projects contributed 8%, 5%, 2% and 2% respectively [29].



**Figure 1.** Total Installed Capacity and Total Generation Capacity of Bangladesh. Adapted from [28].

According to the Power System Master Plan (PSMP) 2010 [30], the forecasted demand for the power based on 7% GDP growth rate shows that only nuclear power plant can fulfill the demand requirement of the nation, as illustrated in Table 3.

**Table 3.** Demand for the power based on 7% GDP [30].

Fiscal Year	Peak Demand (MW)
2016	11,405
2017	12,644
2018	14,014
2019	15,527
2020	17,204
2021	18,838
2022	20,443
2023	21,993
2024	23,581
2025	25,199
2026	26,838
2027	28,487
2028	30,134
2029	31,873
2030	33,708

Therefore, there are lots of prospects in introducing nuclear energy generation in Bangladesh, however, there are also many challenges associated with it. Challenges can be broadly categorised into legal, regulatory, technical, economic, social and political which are, by its nature, also connected with the public policies of the government.

#### 4. Main Problems in Nuclear Power Development in Bangladesh

It is inevitable that there are huge prospects of nuclear energy development in the rapidly growing economic conditions of Bangladesh. However, there remain certain obstacles and challenges to ensure the best usage of nuclear technology. They are:

##### 4.1. Regulatory and Legal Concerns

The main law regarding nuclear power project is the Nuclear Power Plant Act 2015. The Act sets up the Nuclear Power Company of Bangladesh (NPCB) to operate the plant, however, BAEC will remain as an owner of the power plant [31]. However, the law does not contain any provisions for the consequences of any nuclear power plant disaster. Bangladesh needs a comprehensive law on nuclear power production which is necessary in order to guide the future safe energy production. The government should make clear policies to address the impact of nuclear safety regulations and liability rules.

Besides, the agreement between the BAEC and Nuclear Export states that the contract is not a “settled value” contract but instead a “cost in addition to” contract [32]. As it were, as the development work continues, the merchant has the privilege to think of any cost acceleration (in addition to their net revenue) to be consolidated into the agreement sum. The agreement is not comprehensive of fuel costs, operation and upkeep costs, and decommissioning and radioactive waste organization cost toward the finish of its operational life cycle.

In any occasion where the plant is mothballed, cancelled or accidentally damaged, the legal position of the contract between BAEC and ROSATOM enumerates that the government of Bangladesh have to repay the loan with interests. It cannot be denied in such case the risk is extensive, hazardous and improper.

The bitter truth is that man-made disasters in the Third World do not usually give rise to compensatory litigation as can be demonstrated from the Magurchara gas field disaster where neither the government nor the U.S. firm UNOCAL took any responsibility for the gas disaster and paid compensation [33]. Unfortunately, we do not enjoy a robust legal environment where we could ensure justice for the gas disasters, thus it is tough to believe we may ensure justice without a comprehensive legal structure for any nuclear disaster in the future if it happens. Considering the unique case of a country like Bangladesh, where the characteristically fitted gas or coal power plants fail frequently because of bad installation and paucity of apt maintenance, the measure of safety for a sophisticated nuclear power regime is logically questionable. The nuclear disasters, of course, are more devastating and treacherous than gas disasters. Nevertheless, likewise it would be remiss to neglect the fact that lately there has been considerable regulatory changes and developments in the nuclear power generation dynamics in Bangladesh.

The IAEA Safety Standards demand a self-sufficient regulatory body for nuclear operations out of the NPP operating organization. This already exists in Bangladesh, pursuant to local legislative requirements. In fact, the Bangladesh Atomic Energy Regulatory Authority Act (BAERAA) 2012 charter established one such independent authority for the nation. Moreover, its laws allow BAERA to appraise safety standards, protection from radiative hazards, waste management, etc. Moreover, it authorizes transportation, handling, waste safety, disposing activities, and operational dynamics of nuclear facilities within the country. Nonetheless, no matter which authority is entrusted with the appraisal purposes—be it a governmental regulator, a legislative body, or an independent assembly of experts—the body is expected to exceed existing and expected future programmes. Moreover, they should contemplate engaging programmes that have the potential to emerge later in a swiftly evolving global economic climate [34]. As such, it is deemed superior to provide advance guidance on legislate matters in connection to the manner in which a specific region of nuclear activity has to be regulated. The provision for future revisions should not detract its necessity. In fact, it is preferable to leaving the area devoid of regulatory oversight at all, even if done in good faith—considering the environmental, economic, health, and safety grounds.

Consequently, the Bangladesh government has already undertaken necessary measures to streamline the legislative framework to commit to the NPP in order to build, sanction, and operate the nation's inaugural nuclear plant: the RNPP. Furthermore, the BAERA Act is already in force, supplemented by professional input from a panel of local and foreign experts. Besides, the IAEA has also identified a vendor country to help establish an independent regulator to this effect. In this way, BAERA can expect to discharge its regulatory duties without unnecessary intrusion from redundant or overlapping bodies that would otherwise be needed to develop, promote, or maintain nuclear facilities [34]. However, there remains a lot regulatory gaps which need to be developed.

The objectives of energy law ought to be realigned to consider more noteworthy emphasis on sustainability [35]. Furthermore, energy law must focus to utilise more equitable and objective analysis of the risks associated with disasters [36].

#### *4.2. Ensuring Reactor Safety through Technological Means*

The government of Bangladesh wishes to develop, expand and enhance the internationally advanced fission technology and achieve localization. It cannot be denied that such process includes the development of technology from the phrases of the introduction, digestion, and demonstration. However, due to various reasons, currently, the types of imported reactor technology from ROSATOM is complex, and the lack of domestic human resource to deal with such technology will affect the nuclear energy production. Any fission technology will not provide efficient production without the proper domestic introduction and demonstration of such technology [37]. In general, lack of experts on nuclear technology can constitute a great challenge on the efficient production of nuclear power in Bangladesh.

As ROSATOM is a partner for the first nuclear power plant in the country, most of the nuclear technologies adopted are the Russian technologies. The RNPP will be equipped with two VVER-1200 water-cooled, water-moderated power reactors of the AES-2006/V-392M design [37].

The RNPP incorporates the defence-in-depth protection system, which is a multi-layer protection and mitigation system [37]. Any human or man-made accidents can be mitigated using the system ensuring safety to the environment. The system includes five layers of barriers, which will prevent radiation exposure as well as protect people and the environment [37]. The five layers include: preventing, detection, and control of unnatural and suspicious operational failures within the design basis, traction of problematic plant conditions (e.g., preventing accident escalation), mitigating catastrophic events and their consequences, and—lastly—mitigating radiological impacts of significant off-site residuals of radioactive materials [38]. However, still there remains concern regarding the safety issues as the country has not yet developed its own human resources to deal with the insights of this challenging technology. Therefore, ensuring the safety will be a challenging task for the government of Bangladesh.

#### *4.3. Nuclear Waste Treatment*

Nuclear waste and spent fuel accumulation is rapidly growing. By some estimations, the world now contains 180,000 tHM of nuclear waste [39]. The new agendas of Europe and America present a negative impression towards nuclear technology, and thus, they are in the process to closing down some of their nuclear power plants. Such decisions of Europe and America will surely have an impact on the nuclear waste disposal and it is estimated that the growth of nuclear waste can cease [39].

The nuclear waste of the RNPP will not be a huge amount as Bangladesh has aimed for a limited nuclear power generation scale. However, the government should be clear about the policies and initiatives that should be taken for nuclear waste disposal. It is unfortunate that, until now the government has not initiated any related talks, research or policies that provide a comprehensive solution for the nuclear waste disposal. Strong guidelines or plans regarding the disposal of nuclear waste is a must to ensure the safety from radiation to the mass people.



As the government will take more initiatives to establish more nuclear power plants, there will remain questions on the policies of the government to deal with the increasing amount of nuclear waste. Therefore, defining the measures to deal with complex issues of nuclear waste will be a main constraint in the nuclear energy development of Bangladesh.

#### *4.4. Worry about the Security of Nuclear Material*

Although nuclear materials will be strictly supervised by the Government of Bangladesh, however, there remain a certain concern due to the increasing terrorism activities in the region. Only about 3% of uranium-235, which is the core nuclear fuel, is used in nuclear power plants to generate electricity. The usage of 3% of uranium-235 is far below that of the nuclear weapons (more than 90%) [40]. Furthermore, chain fissile reaction in nuclear power production have different control technologies which is very dissimilar from the technology that is used to design nuclear weapons.

Hence, in general, there is no huge threat of the nuclear proliferation from the nuclear power technology, however, the increasing questions on security lead to an anxious public perception relating to the safety of the nuclear materials.

Bangladesh is a state party of the “Treaty on the Non-Proliferation of Nuclear Weapons” and committed to adhere the objective prescribed in the “Treaty”, which comprises “preventing the proliferation of nuclear weapons, promoting the process of nuclear disarmament, and promotion of the peaceful uses of nuclear energy” [41].

However, the Government of Bangladesh has not made any clear statements on the issues of non-proliferation. There should be specific nonproliferation policy and measures from the part of the government. Non-proliferation export control regulations should also be incorporated in order to ensure the security of nuclear fuel operation, transportation and on usage. In the meantime, Bangladesh adhere the principles of using the nuclear power only for the peaceful purposes. Out of other principles, Bangladesh government has been given assurance which includes administering the entire nuclear energy program under constant supervision of IAEA. Besides, Bangladesh government, too, is committed to not transfer nuclear materials to any third party. In addition, the peaceful use of nuclear energy in international cooperation is promised to be always promoted by the Government of Bangladesh.

#### *4.5. Nuclear Energy's Low Economic Competitiveness*

Bangladesh has sufficient natural gas reserves for the near future. In addition, power generation through oil and coal has also reached a commercially mature stage. Such energy production from fossil fuels is cheap as it involves small initial investment and the construction period is also relatively short in comparison to nuclear energy, where the investments are high and the construction period is long, therefore, nuclear power projects are expensive and with huge investment risks. Therefore, nuclear power projects might not be so efficient for a short period of time when compared with fossil fuels power generation. In the case of Bangladesh, the nuclear energy project has become more expensive because of the technology, which needed to be imported and localised in order to ensure the effectiveness of power generation. It is a great disadvantage when initiating nuclear power projects in developing countries.

#### *4.6. Shortage of Uranium Resources*

It cannot be denied that the nuclear fuel resources (mainly uranium) is unequally distributed in the world. The report of the World Nuclear Association (WNA) shows that the world has around 5.47 million tU of uranium resources, costing approximately US\$130/kgU to produce. Among them, just under a quarter are in Australia, about 15% in Kazakhstan, followed by 10% in Russia and Canada, and 6% in South Africa and the US. By comparison, Bangladesh's share is a paltry 0.25% [42]. In addition, the deposits of uranium ore in Bangladesh are relatively small sized and of low category. The average ore of 0.1% and 0.2% grade which is available in Bangladesh cannot be efficiently used in

the production of nuclear energy [43]. Hence, in order to provide cost effective energy in the market through nuclear means, the available uranium resources in Bangladesh cannot be used to carry out large-scale nuclear power generation.

However, BAEC, in several press conferences, has stated that 500 ppm uranium has been discovered in the Sylhet and Moulvibazar areas [44]. They have also continuously repeated that their exploitation for uranium resources is still at the study and research level. They are still trying to find out whether such uranium can be commercially extractable or not [44]. In the meantime, the MoU signed by the Russia and Bangladesh extends to bilateral cooperation regarding exploration of uranium and thorium deposits. In addition, the deposits' development, enrichment, and supply of nuclear fuel as an input for power and research reactors are also covered.

In case of Bangladesh, the domestic production of uranium is not for profitable purposes, and the main objective of such production would only be to meet the demand of RNPP reactors. As the scale of nuclear power production in Bangladesh is still small, it would be a great strategy for the government to meet the uranium demand through domestic supplies.

However, as the scale of producing nuclear energy grows large, the government's choice to import uranium will be a certain option. In addition, it is important to note that the demand for uranium resources of Bangladesh will never impact hugely on the international uranium supply as the country never aims for a large energy production through nuclear means. Indeed, highly experienced countries with nuclear energy production, such as France, Germany, and other few European countries almost fully depend on the import of uranium resources.

## 5. Suggestions and Recommendations for Bangladesh's Nuclear Power Development

The above analysis provides a fruitful picture for our following discussions on suggestions and recommendations:

### 5.1. *Creating a Comprehensive Legal and Regulatory System*

At present, Nuclear Safety and Radiation Control Division (NSRCD) is now working as the regulatory wing of BAEC [45]. There is an independent regulatory body established through Bangladesh Atomic Energy Regulatory Act 2012 [46] with a view to establishing a suitable organization having adequate independence to meet the IAEA/national obligations for ensuring nuclear safety and radiation control in the country. The body is known as BAERA.

For the most part, the common law of torts decides the common risk for most accident related expenses [47]. Be that as it may, for accidents occurring at nuclear power plants, statutes in numerous nations extremely limit the utilization of tort law [48]. As the tort law does not exist in a legal form in Bangladesh, the regulations must also describe the role espoused by criminal law assigning meaning to people's activities on and proceeding the events of any disaster which might happen due to the negligence of the government or the operator. However, until now, the government of Bangladesh has not enacted any laws or regulations addressing such concerns.

Accordingly, Bangladesh also needs a comprehensive Atomic Energy Law [49] to strengthen nuclear safety laws. In addition, nuclear safety fund also needed to be set up in order to organise a comprehensive disaster management team and to compensate the victims on any disasters relating to nuclear power plants. Such laws should also provide optimal liability scheme for the Government of Bangladesh which expounds the following topical challenges: full strict liability for the operator [46]; joint and several liabilities with upstream suppliers [46], with the upstream suppliers' liability [50] being restricted to a negligence standard [51] mandatory liability insurance [51] to be provided by the market to some extent, and above this amount by the government. As the tort law does not exist in a legal form in Bangladesh, such regulations must also describe the potentially decisive role of criminal law in assigning meaning and context to actions of people during and after the occurrence of any disaster arising from negligence of the government, delegated contractors, operator(s), or other third parties.

### *5.2. Enhance Domestic Nuclear Technology Development and Imported Technology Localization*

The nature complex of fission technology is very hard to handle. Therefore, without proper management and efficient human resources, it is impossible to ensure the safety of nuclear reactors. In addition, the enhancement of domestic nuclear technology is also important to marginalise the expenses of nuclear power generation. Simultaneously, the localization process of imported technology will enhance the independent research and development (R&D) of Bangladesh's nuclear power industry. Consequently, to achieve the sustainable goals through nuclear power production, it is imperative for the government of Bangladesh to take the initiatives to develop and localise the domestic nuclear technology.

One of the fundamental points of immediate interest for Bangladesh will be the training and availability of qualified staff to meet the overwhelming needs of proceeding and extending programs. In any case, the 'human resource advancement' needs to incorporate every one of the issues that influence human execution, for example, initiative, administration frameworks, working society, nuclear information administration, and individual states of mind.

Specifically, for the Bangladeshi landscape, it is imperative that a fruitful atomic power program possess a broad framework. Thus, the study will thoroughly analyse nuclear establishments, facilities, investigate associations, administrative facilities, government divisions in Bangladesh and will evaluate whether such bodies have atomic skills and instructive ability to operate the suitable nuclear preparing programs.

### *5.3. Cost Minimization of Nuclear Power Generation and Promoting Market Competitiveness*

Owing to various factors ranging from economies of scale, carbon lock-in, and sluggish development in nuclear technology, fossil fuel-based power remains substantially cheaper than nuclear power. In fact, the initial capital outlay in both construction, design, material procurement, and technological industry complex means that nuclear power projects can be undertaken only after a massive governmental commitment is made. By comparison, private ventures abound in the fossil fuel industries. However, it is undeniable that the increasing prices of gas, coal and oil provide a good prospect for nuclear energy in future. The efficient amount of power production through nuclear means cannot be discounted either. The short supply of oil and natural gas resource has initiated the developing countries to choose nuclear energy as their sustainable option. However, it is particularly important for Bangladesh to blend the nuclear technology with local expertise and enhance domestic technology to minimise its cost and improve its market competitiveness.

### *5.4. Accelerate a Cleaner Process of Nuclear Technology Development*

Managing nuclear waste will be a big challenge for Bangladesh though the country is targeting a small scale of nuclear power generation. It is also true that the amount of nuclear waste will drastically increase with the new installment of nuclear power plants in the approaching years. Hence, cleaner nuclear reactor and developed nuclear waste disposal technology must be initiated by the government.

### *5.5. Accelerate a More Efficient Process of Reactor and Nuclear Fuel Cycle Development*

The expected uranium demand in Bangladesh will be on a small scale, which could be met with the domestic uranium production supply. Bangladesh is expecting to discover limited amounts of uranium resources, which would actually be limited to less than 1% of the total resources of the world. Importing uranium is always an alternative approach that the government might take, however, it is very important to remember that such an approach conflicts with other international political issues. Therefore, it is always suggested to develop efficient reactors which can produce large amount of electricity with less uranium resources. Some of the aspects of fast breeder reactor technology, spent fuel recovery and utilization technology can be used to achieve this goal.

### 5.6. Undertake Judicious Public Relation Work to Spur Public Acceptance

The Government of Bangladesh ought to likewise clarify explanations on their methodologies towards the most imperative focuses identifying with nuclear power plant, for example, radiological assurance of laborers, radiological insurance of open, radioactive waste administration and ecological radiological reconnaissance. Open mindfulness and contribution are likewise rudimentary before setting up the nuclear power plant. Though exceptionally progressed and refined new reactors may decrease perils in light of “characteristic” security features, for instance, “latently sheltered” measures made by the era III reactor, we assume that any country that does not give genuine straightforwardness and enable open commitment with respect to atomic issues ought to never use atomic vitality. Along these lines, the Government of Bangladesh should contribute convincing consideration work to keep up open responsibility. It should be yielded that atomic expert expansion is in the meantime social, political, and financial, and along these lines, the Government of Bangladesh should take the perspectives of masters in different fields before totally chipping away at the nuclear power era.

Other than these huge steps, the organization of Bangladesh ought to moreover have strong state commitment in controlling fiscal change, centralization of national vitality masterminding, endeavours to interface imaginative advances to a national restoration, effect of technocratic conviction framework on course of action decisions, subordination of troubles to political administration, and low levels of urban activism which are convincing components in supporting the augmentation of atomic power.

It cannot be denied that with the improvement of the domestic nuclear technology, the expenses of power production through nuclear means will be reduced and security measures will be enhanced. Hence, it is important for the government of Bangladesh to learn from the countries, such as the United States of America, Germany, France, South Korea, China and Japan, to carry out effective publicity to maintain public acceptance for nuclear energy in the future. Additionally, the government must efficiently manage and supervise the nuclear power operations in order to thwart the spread of nuclear material. Last but not the least, the government should fund and sustain nuclear research and development action concerning all the above issues.

## 6. Conclusions

Bangladesh has identified atomic power as a keystone of a sustainable energy framework. Usage of RNPP is a piece of energy security plan of Bangladesh and development of 2000 MW atomic limit has turned into an integral piece of the Vision 2021 of Bangladesh Government. Pragmatic strides towards setting up national atomic power framework for building RNPP by 2020 have as of now been taken and along these lines, government ought to consider building up an instrument of coordination among Bangladesh, the recognised enterprises and the IAEA.

After a large portion of a century of fruitful advancement, with superb achievements and eagerness and indistinct feedback, nuclear power has made a substantial commitment to human advancement. No other energy innovation has such an across the board widespread demand, spanning from nuclear material science, physical sciences, chemistry, biology, medicine, and other disciplines like software engineering, psychiatry, or pharmacy. The education to utilise atomic innovation has been aggregated amid the most recent fifty years and must be managed promote irrespective of the part nuclear energy will play in 21st century onwards.

The safety and security of the present existing nuclear establishments and particularly the new ones that are being manufactured and anticipated that would be inherent in the creating scene, which will frankly rely on upon how countries, governments, and regional powers learn to implement, design, safeguard, exchange and further develop nuclear learning and talent around the world.

This study is particularly important as it provides an opportunity to revisit research concerns on the topical subject of nuclear power which, paradoxically, has not been thoroughly addressed in Bangladesh and make fresh and original legal and scholarly contributions, focused on Bangladesh, that add to the corpus of knowledge in the nuclear field globally. This study thus introduces and develops new knowledge on prospects and challenges of nuclear power for electricity generation

in Bangladesh. It extensively and exhaustively deals with both prongs of the development of an effective nuclear power plant by aptly analysing the current status. The study, thus recommends the government of Bangladesh to develop a sufficiently effective nuclear power plant and ensure the nuclear safety and security.

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